International Research Center for Elements Science
- Photonic Elements Science -

http://www.scl.kyoto-u.ac.jp/˜opt-nano/index-e.html

Prof
KANEMITSU, Yoshihiko
(D Eng)

Assoc Prof
MATSUDA, Kazunari
(D Eng)

Assist Prof
TAYAGAKI, Takeshi
(D Sc)

Assist Prof (SER)
YAMAMOTO, Shinpei
(D Eng)

PD
ITO, Hisashi
(D Sc)

Students

HIRANO, Daisuke (D1)
HOSOKI, Koshin (M2)
MATSUNAGA, Ryusuke (M2)
HIGUCHI, Shinya (M2)
YASUDA, Hideki (M2)
TAGUCHI, Seiji (M1)
YOSHIKAWA, Kohei (M1)
UEDA, Akihiro (M1)

Scope of Research

Our research interest is to understand optical and quantum properties of nanometer-structured materials and to establish opto-nanoscience for creation of innovative functional materials. Optical properties of semiconductor quantum nanostructures and strongly-correlated electron systems in low-dimensional materials are studied by means of space- and time-resolved laser spectroscopy. The main subjects are as follows: (1) Investigation of optical properties of single nanostructures through the development of high-resolution optical microscope, (2) Development of nanoparticle assemblies with new optical functionalities, and (3) Ultrafast optical spectroscopy of excited states in semiconductor nanostructures.

Research Activities (Year 2007)

Publications

Ito Y, Matsuda K, Kanemitsu Y: Mechanism of Photoluminescence Enhancement in Single Semiconductor Nanocrystals on Metal Surfaces, *Phys. Rev. B*, **75**, [033309-1]-[033309-4] (2007).

Matsuda K, Nair S V, Ruda H E, Sugimoto Y, Saiki T, Yamaguchi K: Two-exciton State in GaSb/GaAs type II Quantum Dots Studied Using Near-field Photoluminescence Spectroscopy, *Appl. Phys. Lett.*, **90**, [013101-1]-[013101-4] (2007).

Tamada Y, Yamamoto S, Nasu S, Takano M, Ono T: Well-Ordered $L1_0$-FePt Nanoparticles Synthesized by Improved SiO_2-Nanoreactor Method, *Appl. Phys. Lett.*, **90**, [162509-1]-[162509-4] (2007).

Presentations

Nano-imaging Spectroscopy of Semiconductor Quantum Structures, Matsuda K, 3rd Handai Nano Symposium, 26–28 October 2007, Osaka, Japan (Invited).

Optical Probing of a Single Carbon Nanotube, Matsuda K, JSPS 2nd Japan-Germany Nanophotonics Seminar, 24–28 October 2007, Yonago, Japan (Invited).

Dynamics of Electron-Hole Plasmas in Highly Excited GaN-based Ternary Alloys, Hirano D, Kanemitsu Y, 16th International Conference on Dynamical Processes in Excited States of Solids (DPC07), 17–22 June 2007, Segovia, Spain.

Grants

Kanemitsu Y, Study of Highly Excited State in Semiconductor Nanostructures by Means of Time and Spatially Resolved Spectroscopy, Grant-in-Aid for Scientific Research (B), 1 April 2006–31 March 2008.

Matsuda K, Explorer of Optical Properties and Application of Quantum Optical Devices in an Individual Carbon-Nanotube by Optical Nanoprobing, Grant-in-Aid for Young Scientists (A), 1 April 2005–31 March 2008.

Awards

Matsuda K, Explorer of Nanoimaging Spectroscopy: Wavefunction Mapping of Semiconductor Quantum Structures, Award for Research Promotion, Marubun Research Promotion Foundation, 5 March 2007.

Matsuda K, Electronic States Mapping of Semiconductor Quantum Structures by Near-field Nanoimaging Spectroscopy, 1st Physical Society of Japan Award for Young Scientist, 21 September 2007.

Dynamics of Nonlinear Photoluminescence from $SrTiO_3$

Transition metal oxides have attracted a great deal of attention as new device materials due to their wide variety of fascinating and multifunctional properties. With its unique electrical and optical properties, $SrTiO_3$ is one of the most important oxide materials. We studied the behavior and dynamics of polarons in non-doped and electron-doped $SrTiO_3$. The photoluminescence (PL) decay dynamics are dependent on both the photogenerated and the chemically doped carrier density in $SrTiO_3$ (Figure 1). The PL dynamics are well explained using a simple model that includes radiative bimolecular recombination and nonradiative Auger recombination processes of polarons.

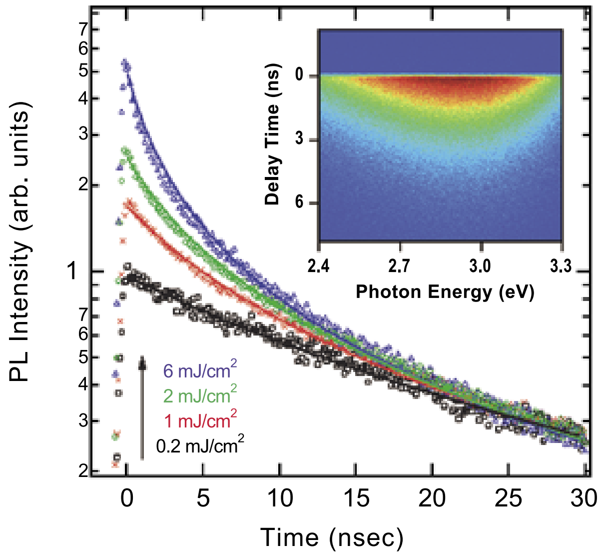

Figure 1. Excitation density dependence of PL dynamics in $SrTiO_3$. The inset shows streak image of PL decay.

Multiexciton Recombinations in a Single Carbon Nanotube

Electronic and optical properties of single-walled carbon nanotubes (SWNTs) have attracted much attention from the fundamental physics viewpoint. The recent discovery of efficient PL from isolated semiconducting SWNTs has stimulated considerable efforts in understanding optical properties of SWNTs. We studied the temperature and excitation intensity dependence of exciton luminescence in single SWNTs. The linear temperature dependence of the PL linewidth in a single SWNT implies that the exciton dephasing is dominated by the interaction between the exciton and the phonon mode with very low energies under lower excitation conditions. Saturation of the PL intensity and broadening of the PL linewidth in a single SWNT occur simultaneously with an increase in the excitation laser intensity. Our findings show that the rapid exciton-exciton annihilation through multiparticle Auger recombination broadens the homogenous PL linewidth.

Photoluminescence Enhancement and Quenching of Single CdSe/ZnS Nanocrystals on Metal Surfaces

Colloidal semiconductor nanocrystals with high PL quantum efficiencies have been extensively studied both from the viewpoint of fundamental physics and with consideration for the potential applications to electronics and biotechnology. The interfaces between metals and nanocrystals play complex and essential roles in the optical responses of semiconductor nanocrystals on metals. The detailed understanding of interactions between nanocrystals and metal surfaces are very important to enhance the PL intensity of nanocrystals in conjunction with the improvement of the PL efficiency of nanocrystals. We studied the mechanism of the PL enhancement and quenching of CdSe/ZnS nanocrystals on rough Au surfaces in Figure 2. Single nanocrystal spectroscopy revealed that the PL enhancement depends strongly on the excitation wavelength and liner-polarization angle due to the localized plasmon excitation. The simulated electric-field distribution was shown in the inset of Figure 2. The observed PL enhancement and quenching are sensitive to the nanocrystal size. The polarization- and size-dependent PL enhancement and quenching are determined by the balance between the resonant energy transfer from the nanocrystal to the Au surface and the electric field enhancement.

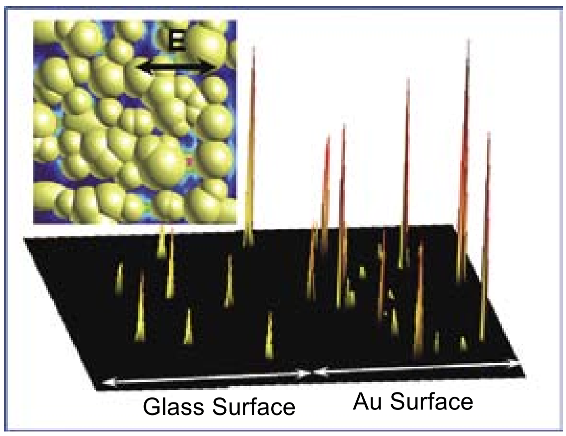

Figure 2. PL image of single CdSe/ZnS nanocrystals on glass (left side) and metal substrate (right side). Inset shows simulated electric-field distributions induced by surface plasmon.